FY 2002 Performance

➢ Continue improving the YBCO performance on meter lengths of IBAD MgO with a goal of bringing it up to par with YBCO on IBAD YSZ.

- The problem of producing lengths of highly-polished substrate tape by a commercially viable process (i.e. electropolishing) has been solved.

- The texture of continuously-processed meters of IBAD MgO is routinely better than for our best IBAD YSZ.

- A robust buffer layer ($SrRuO_3$) has been fully developed through the continuous processing of meter lengths. Another candidate ($LaMnO_3$) is under development with Oak Ridge

- A high-I_c , continuously-processed meter has not yet been produced.

FY 2002 Performance (continued)

➢ Continue improving the YBCO performance on meter lengths of IBAD MgO with a goal of bringing it up to par with YBCO on IBAD YSZ (2).

▪ The quality of continuously processed (c.p.) substrate tape and IBAD MgO layers was confirmed by cutting 9 samples from a meter and batch processing with PLD $SrRuO_3$ and YBCO.

➔ Result – texture is very uniform and average J_c (16 bridges) is 1.2 MA/cm^2 at 1.1 μm thickness.

▪ The quality of c.p. PLD $SrRuO_3$ was confirmed by cutting a sample from the end of a meter and batch processing with PLD YBCO …

➔ Result – 3.9° FWHM, in-plane, and 1.2 MA/cm^2 @ 1.9 μm.

▪ also, we found excellent crystalline alignment and T_c for completely c.p. tapes.

➔ Result – YBCO in-plane texture ranged from 3.0 (!) to 4.9° FWHM for the last six tapes, and T_cs ranged from 89 – 92 K.

FY 2002 Performance (continued)

➢ Continue improving the YBCO performance on meter lengths of IBAD MgO with a goal of bringing it up to par with YBCO on IBAD YSZ (3).

- The best I_c values for completely c.p. tapes are in the 60 – 90 A range for few-cm-long sections.

- Conclusion: three of the four continuous-processing steps (substrate polishing, IBAD MgO layers, PLD $SrRuO_3$ buffer) are "ready" -- the PLD YBCO step is presently the only limiting factor.

- We suspect that our YBCO difficulties result from the use of a new laser, which replaced the industrial laser and became operational in April. This laser produces higher energy and a larger spot on-target, resulting in dramatically different plume properties that we have not yet learned how to utilize.

FY 2002 Performance (continued)

➢ Work toward reducing the number of layers in the IBAD MgO process.

▪ The number of buffer layers was reduced from two (YSZ/CeO_2) to one ($SrRuO_3$). $LaMnO_3$ (ORNL) and $SrTiO_3$ are also candidates.

▪ More importantly, the total thickness of the layers between metal and superconductor was reduced from about 600 nm to less than 150 nm, and, we believe, can be further reduced without sacrificing performance.

▪ Present architecture:

YBCO	1-4 µm
$SrRuO_3$	50 nm
homoepitaxial MgO	25 nm
IBAD MgO	15 nm
nucleation layer (e.g. Y_2O_3)	35 nm
Hastelloy C-276 substrate	100 µm

FY 2002 Performance (continued)

➢ Develop a better scientific understanding of how thick multilayers improve tape current.

- Multilayers improve I_c for YBCO over 2 μm thick by reducing porosity above this level, but they do not alter the general trend of rapidly decreasing J_c (t) observed in thinner films.

- Porosity reduction does not result from planarization by the Sm123 interlayers, but rather from inhibition of cumulative roughening. The mechanism for this is not presently understood.

- The magnetic field dependence of single-layer YBCO is more pronounced for thicker films: multilayers partially reverse this trend (i.e. thick multilayers perform like thinner single-layers in field).

- Grain growth in the superconductor appears unaffected by the Sm123 interlayers.

FY 2002 Performance (continued)

- Provide assistance in transferring our best IBAD and PLD technologies to the Los Alamos Research Park.

- Participated in facility design and lab space layout.

- Developed specifications for reel-to-reel polishing unit and assisted in design of deposition systems.

- Determined optimum deposition parameters for 200 W industrial excimer laser and used it to demonstrate high speed deposition (15 m/hour for 1 μm YBCO) and high current tape (225 A).

- Transferred industrial laser to Research Park PLD laboratory and provided guidance in integrating it with the new deposition chamber.

- Successfully tested the Research Park's electropolished substrate tape by depositing IBAD MgO/$SrRuO_3$/YBCO and measuring J_c (1.5 MA/cm^2 @ 1.65 μm)

FY 2002 Performance (continued)

➢ Continue the collaboration with Oak Ridge National Laboratory with a goal of coating meter lengths of their textured/seeded nickel using our continuous PLD process.

- The J_cs for Los Alamos PLD YBCO on Oak Ridge-supplied RABiTS tape were < 0.1 MA/cm^2

- Oak Ridge was consulted about PLD deposition parameters used for their high-J_c deposition on similar RABiTS – they were essentially the same as those used at Los Alamos.

- It was subsequently learned that the tension required in the Los Alamos deposition system exceeds that which can be tolerated by the pure nickel tape at 760° C.

- However, there were several other collaborations with Oak Ridge in 2002, two of which were very successful:

An Oak Ridge – Los Alamos collaboration produced excellent results on IBAD YSZ

- Los Alamos sent a high-quality IBAD YSZ sample to Oak Ridge

- Oak Ridge sputtered a CeO_2 buffer layer on the YSZ, and produced a thick YBCO film using the BaF_2 process

Result:

- YBCO thickness – 2.7 µm
- Measured I_c (77 K, 0.5 T || c) – 60 A/cm-width
- I_c (extrapolated to self-field) – 270 A/cm-width
- extrapolated J_c ~ 1 MA/cm^2

- This performance is comparable to the best single-layer results achieved at Los Alamos and other institutions using IBAD YSZ.

Another Oak Ridge – Los Alamos collaboration produced excellent results on IBAD MgO

- Los Alamos sent a high-quality IBAD MgO sample to Oak Ridge
- Oak Ridge sputtered a $LaMnO_3$ buffer layer on the MgO
- The sample was returned to Los Alamos for PLD YBCO

Result:

- YBCO texture – 5.2° FWHM (in-plane); 1.8° FWHM (out-of-plane)
- YBCO thickness – 1.65 μm
- J_c (75 K, self-field, two bridges) – 1.3 and 1.5 MA/cm^2
- equivalent I_c – 230 A/cm-width

- This performance is comparable to the best single-layer results achieved by Los Alamos on IBAD MgO.

Research Integration

A CRADA with IGC is our strongest industrial collaboration

(2000 – present)

- Technology transfer of Los Alamos IBAD/PLD processes for scale up of coated conductors at IGC SuperPower

  - working visits at both locations
  - frequent communication
  - sample exchange and characterization
  - equipment loans
  - research on IGC-polished substrates
  - licensing of Los Alamos patents

- Excellent results achieved in a very short time

Research Integration (continued)

We have also been involved in two other coated conductor CRADAs

- 3M CRADA (1997 – present)
  - IBAD modeling
  - *in-situ* monitoring
  - sample exchange and analysis
  - interest in IBAD MgO

- ASC CRADA (1996 – 2001)
  - sample exchange and analysis
  - interest in IBAD MgO

Research Integration (continued)

We have participated in three strong inter-Lab collaborations

- Oak Ridge National Laboratory
  - sample exchange, coating and characterization
  - "Parans" Paranthaman – Strategic Research Session
  - Ron Feenstra – Strategic Research Session

- Argonne National Laboratory
  - Raman and synchrotron characterization of RE123 interfaces
  - Vic Maroni – Strategic Research Session

- Brookhaven National Laboratory
  - J_c (B,T) characterization of Y-Sm multilayers
  - Mas Suenaga – Strategic Research Session

Research Integration (continued)

In total, we took part in 25 collaborations in 2002

Organization	Contact	Description
3M Company (CRADA)	Jonathan Storer	basic IBAD research, sample exchange and analysis
American Superconductor Corporation	Xi Li	supply IBAD YSZ for TFA deposition
Argonne National Laboratory	Balu Balachandran	coat ISD samples
Argonne National Laboratory	Mark Kirk	supply samples for flux-pinning studies
Argonne National Laboratory	Vic Maroni	Raman and synchrotron anaylsis of RE123 interfaces
Brookhaven National Laboratory	Mas Suenaga	J_c (B,T) on multilayers
California Institute of Technology	Harry Atwater	develop IBAD diagnostics
Case Western Reserve University	David Farrell	supply flux transformers for biosusceptometer
Imperial College of London	Judith Driscoll	supply samples for various experiments
Intermagnetics General Corp. (CRADA)	Venkat Selvamanickam	IBAD/PLD technology transfer, substrate research
Lawrence Berkeley Laboratory	Rick Russo	supply substrates for IBAD MgO
Microcoating, Inc.	Shara Shoup	coat CCVD samples
Motorola, Inc.	Keith Beardmore	supply data for IBAD modeling
Nat'l Institute for Standards and Tech.	Jack Ekin	supply tape for strength testing
National Renewable Energy Laboratory	Raghu Bhattacharya	coat textured metal substrates
Oak Ridge National Laboratory	Ron Feenstra	test BaF_2 YBCO on IBAD
Oak Ridge National Laboratory	Amit Goyal	test IBAD on smooth as-rolled tape
Oak Ridge National Laboratory	Dominic Lee	coat buffered RABiTS tape
Oak Ridge National Laboratory	"Parans" Paranthaman	test $LaMnO_3$ buffer layers on IBAD MgO
Massachusetts Institute of Technology	Yuki Iwasa	supply tape for quench propagation measurement
Sandia National Laboratory	Paul Clem	coat buffered textured metal substrates
Stanford University	Bob Hammond	perform x-ray, TEM of coevaporated YBCO
University of Kansas	Judy Wu	supply IBAD for Hg-HTS
University of Michigam	Peter Smerka	supply experimental IBAD data
Zentrum fur Funktionswerkstoffe	Herbert Freyhardt	test ZFW's IBAD YSZ on various substrate tapes

FY 2002 Results

1. Demonstrated that low-cost, high speed, reel-to-reel electropolishing produces an ideal surface for deposition of IBAD MgO, resulting in 1.5 MA/cm^2 @ 1.65 μm $\Rightarrow$ 248 A/cm-width.

2. Employed a new amorphous nucleation layer (Y_2O_3) that expands the process window of IBAD MgO, eliminating the need for real-time RHEED monitoring of the growing film.

3. Developed IBAD MgO into a stable, reproducible continuous process that routinely yields meter lengths with texture (MgO) of 7 – 9 degrees in plane and ~ 3 degrees normal to the film plane.

4. Built on long-standing experience with $SrRuO_3$ to develop it into a buffer layer for IBAD MgO with excellent structural and chemical properties, and unprecedented ability to yield enhanced YBCO texture (3.0 degrees in-plane, and 1.1 degrees out-of-plane have been achieved).

5. Reduced the number of buffer layers from two (YSZ/CeO2) to one ($SrRuO_3$), while improving I_c reproducibility (75 of last 100 samples had equivalent I_c > 100 A/cm-width).

FY 2002 Results

6. Reduced the thickness of intermediate oxide layers from over 600 nm last year to less than 150 nm this year, without reducing performance.

7. Achieved I_c = 60-90 A on short, continuously-processed tapes.

8. Showed that thick Y-Sm multilayers offer not only higher I_c, but also a significant improvement over thick single layers in an external magnetic field.

9. Found that Sm123 interlayers suppress roughness-induced porosity, but not by simple planarization of the superconductor surface.

10. Demonstrated up to 1.3 MA/cm^2 @ 3 μm with multilayers on IBAD MgO/$SrRuO_3$.

11. Assisted with the design and set-up of the new Los Alamos Research Park facility, and transferred the 200 W industrial excimer laser to the Research Park PLD laboratory.

12. Participated in two CRADAs and 23 other informal collaborations with companies, national laboratories and universities.

FY 2003 Plans

Distribute IBAD MgO to our industrial partners and national laboratory collaborators for deposition of YBCO, and work with them individually to achieve optimum performance with their respective deposition processes.

Support both IGC and the Research Park in scaling up the latest IBAD and PLD technologies.

Solve the problem(s) preventing us from achieving high-current YBCO on IBAD MgO/$SrRuO_3$ (Goal: 100 A in a meter), and incorporate multilayer technology to reach 200 A in an IBAD MgO meter.

Optimize the thickness of each layer in the IBAD MgO architecture with a goal of reducing the total nonsuperconducting layer thickness to below 100 nm without reducing performance.

Deposit YBCO on meter lengths of IBAD MgO with the Oak Ridge $LaMnO_3$ buffer layer. Goal: 100 A.